
(19)  Canadian Intellectual Property Office Office de la Propriété Intellectuelle du Canada (11) CA 618826 (13) A
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(12)
(21) Application number: 749938 (51) Int. Cl:
(22) Date of filing: 21.04.1958

(30) Priority:
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(54) RECOVERY OF NICKEL, COBALT AND OTHER
VALUABLE METALS (57) Abstract:

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This invention relates to a process for recovering nickel, cobalt, copper, zinc and manganese values or any of them from oxidic ores including silicious ores containing the same in admixture with iron. More particularly, the invention relates to the leaching of such valuable metals from lateritic ores particularly those of the limonite type.

In the recovery of nickel from nickeliferous ores, it has heretofore been suggested to reduce such ores at elevated temperatures and thereafter to extract nickel from the ore by leaching with ammoniacal leach liquor. It has also been suggested that nickel be leached from a certain type of nickeliferous ore with sulfuric acid. However, so far as we are aware, there has not been any industrially successful process for extracting nickel from low grade nickeliferous oxidic ores or minerals, say ores containing less than 2% of nickel, by leaching with sulfuric acid.

It is an object of this invention to provide an improved process whereby nickel can economically be directly leached from low grade nickeliferous oxidic ores as well as from concentrates of such ores with sulfuric acid and in substantially quantitative yields.

It is a special object of this invention to provide an improved process whereby both nickel and cobalt can be leached simultaneously from oxidic minerals bearing them and in substantially quantitative yields.

It is another special object of this invention to provide an improved process for directly and substantially completely leaching nickel, cobalt, copper, zinc and manganese values from low grade, nickeliferous, limonitic ores bearing them and containing other not so valuable minerals, including

5 at least 40% iron, with sulfuric acid leach liquor and with a consumption of sulfuric acid not more than 35% of the weight of the dry ore treated; such consumption depending upon the composition of the ore, particularly its alumina and magnesia content.

10 Another object is to provide a process for the recovery of nickel, cobalt and other non-ferrous metals from ore concentrates or concentrated ores higher in nickel, cobalt, manganese and chromium content, such as the concentrated ore produced from low grade nickeliferous, lateritic limonite ore found in New Caledonia.

Other objects and features of the invention will be apparent from the more detailed description which follows.

15 Specifically considered, the invention is concerned with a process for the ultimate recovery of nickel, cobalt, copper, zinc and manganese values or any of them from lateritic ores and concentrated ores derived therefrom, and includes leaching such ores with an aqueous solution of sulfuric acid in a quantity not substantially more than that which will be taken up by the non-ferrous metal content during the hot sulfation treatment subsequently employed, in which treatment the acid slurry of the mineral is heated under pressure to a temperature of at least about 400°F. and preferably above 450°F. if maximum recovery of nickel is desired, or to a temperature as low as about 350°F. if the recovery of cobalt is the primary consideration, the pressure in all instances being at least equal to the vapor pressure of the solution. Temperatures up to about 500°F. may be successfully used for both nickel and cobalt recovery. Temperatures in excess of 500°F. may also be used, but any small improvement in extraction or acid consumption does not compensate for increased equipment costs.

When low grade nickeliferous ores (containing less than 2% nickel) are treated, from about 15 to 35% acid in relation to the weight of the dry ore is employed. A rough approximation of the amount of acid required in any particular instance can be ascertained from the ore or concentrate analyses by calculating the theoretical quantity of acid required to convert the nickel, cobalt, zinc and copper content to the bi-sulfate form, the aluminum to the basic bi-sulfate form and the magnesium to the sulfate form. If manganese and chromium are present in appreciable amounts (more than about one per cent) additional acid is required in varying amounts, but in any event the total or optimum amount of acid can be determined by test under the conditions and in the equipment to be employed. Too little acid will lead to less than optimum yields of the desired non-ferrous metals, and too much acid will cause leaching of excessive amounts of iron and aluminum and/or a waste of sulfuric acid, either of these results being detrimental to the economic success of the whole recovery operation. An amount of acid between 15% and 100% of the ore weight will work satisfactorily with any of the raw or concentrated ores treated up to the present time. In treating concentrates containing more than about 2% nickel, from 25% to 100% acid usually gives good results.

The water present during the leaching operation serves the function of dissolving the metal content solubilized by the action of the acid. In the treatment of the low grade nickel ores, ore suspensions initially containing from about 20 to 50% solids are feasible, 40 to 50% solids being preferred leading to concentrations of 25 to 35% during the treatment upon heating in the reactor. In the treatment of concentrates or high grade minerals or concentrates of 2 to 4%

nickel or more, water requirements may be higher, and hence the maximum possible solids content of the suspension during the hot leaching treatment may be 15% or 10%, or even lower.

The water, ore and acid can be brought together by any procedure in any order, but practically it is preferred that the water or most of it be first mixed with the ore in a quantity adequate to provide a flowable slurry or suspension, that the resulting mixture be flowed into an autoclave and that the acid be added in concentrated form. Substantially more water than is required to dissolve the sulfated nickel and other solubilized metals, or, than is required to provide a flowable suspension should be avoided, for the larger the amount of water, the greater the bulk and the larger the equipment required to effect the leaching and other operations.

More water also leads to more iron in the leach liquor to be separated from the non-ferrous metals. Where the recovery of the nickel content is paramount, the ore-liquid ratio should be such as will provide a leach liquor having a nickel concentration of not more than 7 to about 10 grams per liter.

The process may be advantageously used to leach the nickel and other valuable metals from limonitic ore containing less than 2% nickel and only fractional percentages of the other metals, an example of such ores being the lateritic limonitic ores found in Cuba, which also contain on the average at least 40% of iron, about 9 to 11% of alumina, and magnesia in small percentages, often less than 3%.

The process may be typified by the leaching procedure applied to a lateritic limonite ore found in the Moa Bay area of Cuba and having the following average analysis:

	<u>Ingredient</u>	<u>Percent</u>
5	Nickel	1.35
	Cobalt	0.14
	Manganese	0.9
	Copper	0.02
	Zinc	0.04
	Iron	47.
10	Alumina	10.
	Magnesia	1.
	Other constituents and water of hydration	39.55
		<hr/>
		100.00

By pulping such ore with a quantity of water which will yield a suspension containing about 45% solids, then heating the suspension to a temperature of about 450 to 485°F., and holding the suspension at that temperature for a period of two hours, after having introduced concentrated sulfuric acid in an amount equal to 22.5% of the weight of the dry ore treated, such acid being added after the suspension has reached reaction temperature, approximately 95% of the nickel and cobalt contained in the ore will thereby be leached from the ore and recovered in solution in a product liquor having the following average analysis:

	<u>Ingredient</u>	<u>Grams per Liter</u>
25	Nickel	6.
	Cobalt	0.6
	Manganese	2.
	Copper	0.1
	Zinc	0.2
	Iron	1.
30	Aluminum	3 to 7
	Magnesium	less than 5

By proceeding in the manner prescribed, substantially all of the nickel, cobalt, and other valuable metals can be leached from such ore and obtained in the product liquor in a much higher ratio with respect to other metal content than contained in the ore. Yet, this result can be achieved with a consumption of sulfuric acid of the order of 15 to 35%

based on the weight of the dry ore and normally requires an amount of sulfuric acid less than 25% of the weight of the ore.

The application of the process of the invention to a high grade nickel ore may be typified by the leaching procedure applied to an ore concentrate obtained from a raw New Caledonia ore by screening or wet cycloning, the concentrate having the following metal content:

	<u>Ingredient</u>	% by Weight on Dry Basis
10	Nickel	3.15
	Cobalt	3.77
15	Iron	14.3
	Aluminum	4.83
	Magnesium	1.64
	Manganese	19.5
	Chromium	8.0
	Copper	0.006
	Zinc	Trace

20 The concentrate is pulped in water in a quantity producing a slurry concentration of 15% solids and the resulting suspension is heated to a temperature of about 475°F. at a pressure of 550 p.s.i.g. Thereupon concentrated sulfuric acid is introduced into the suspension in the quantity amounting to 25 65 - 75% of the dry weight of the concentrate. The heating is continued for two hours during which time the mass is agitated by direct steam. Thereupon the mass is cooled to 220°F. and blown down. After further cooling the leach solution is separated from the spent concentrate. The yield of nickel will be about 94% and of cobalt about 95%. The leach solution will contain about 1.32 gm. per liter of iron. Other metal compounds which also will be found in the solution include those of manganese, chromium, copper, aluminum and magnesium.

All of the sulfuric acid required for the leaching process may be introduced at the beginning of the leaching period and may be added prior to heating to leaching temperature. Under such circumstances, the concentration of the sulfuric acid in the leach liquor will be at the highest value ever encountered in the process at the instant the acid is added. The concentration would naturally depend on the ore/liquid ratio used in the process. Surprisingly, the small amount of acid added in relation to the acid-consuming constituents in the ore, initially reacts with the iron, aluminum and other ingredients and is largely neutralized, but upon heating at the high temperatures herein described the nickel, cobalt and other valuable metals become selectively sulfated.

During the leaching most of the sulfuric acid is consumed, but not all of it. As the leaching process approaches its terminal stage the concentration of sulfuric acid will fall and leaching of the nickel and cobalt values will continue to take place at a reduced but satisfactory rate. On cooling, the concentration of sulfuric acid in the liquor may be as little as 15 grams per liter, at least part of the acid being regenerated or released from the bi-sulfate salts in changing to sulfate salts. Under preferred conditions, however, the resultant terminal sulfuric acid concentrations of the cool liquor are of the order of 20-30 grams per liter.

In accordance with a preferred procedure for the recovery of leached metals, the product leach liquor, advantageously after having had its acidity reduced to a pH value of 2-3, is treated with hydrogen sulfide to precipitate the dissolved metal content. More in detail, this embodiment may be carried out by separating the partially neutralized

product leach liquor from the spent ore in a countercurrent decanting system, and the nickel, cobalt and other metals are recovered from the liquor by the introduction of hydrogen sulfide into the liquor at a temperature of about 250° to 270°F. under a pressure of 125 pounds. The initial step of neutralizing the free acid in the product leach liquor can be omitted, but not without considerable disadvantage, for when the pH is below a value of about 2, higher temperatures and pressures are required during the precipitation, i.e. temperatures higher than 270°F. and somewhat higher pressures. The hydrogen sulfide precipitates the nickel and cobalt content from the leach liquor as well as any copper, zinc or other similarly reacting metals which might be present while leaving in solution iron, aluminum and manganese or other similarly reacting metals. The precipitated metals are in the form of their sulfides and the reaction produces sulfuric acid in the solution.

The metal sulfides thereupon are separated from the product leach liquor by decanting, centrifuging or filtering. The nickel and cobalt are thereafter separated from the other metal compounds or from each other by any suitable method, these methods not being part of the present invention.

In the separation or recovery of the nickel and other valuable metal values from the product liquors resulting from the leaching process, another procedure is first to neutralize any excess or terminal acid in these solutions and then to adjust the pH of the product liquor to a range of 3.5 to 4.5 for the purpose of precipitating the dissolved iron and aluminum, provided the precipitation is to take place at or near atmospheric pressure and at reduced temperatures. These two steps can be carried out as separate

operations, or they can be carried out successively in a single operation. They are preferably performed on the product liquor alone after the temperature of the slurry has been reduced and after the product liquor has been separated from the exhausted ore.

In the neutralization of the excess acid and adjustment of the pH of the product liquor to precipitate the dissolved aluminum and the small amount of iron present, limestone, lime or other inexpensive alkaline neutralizers may be injected into the ore slurry at the end of the leaching period.

It has also been found advantageous to employ additional ore in the form of a slurry to neutralize excess acid in the manner described hereinbefore. In another embodiment of the invention, the neutralization of the excess acid can be carried out with a slurry of a mineral which is of the same general composition and from the same location as the ore being leached but which does not contain nickel or cobalt in sufficiently high concentration or contains other undesirable constituents that would make the direct leaching of the nickel and cobalt values uneconomical from such material. Such ores are referred to herein as off-grade lateritic ores. If one or the other of these off-grade minerals referred to are used to neutralize the excess acid, it is advantageous to add subsequently some lime, limestone or other alkaline agent to adjust the pH of the product liquor to the level required for satisfactory precipitation of the mentioned aluminum and iron contamination.

Under those conditions wherein the product liquor temperature has been reduced below the leaching temperature, as an alternative to the complete or substantially complete precipitation of the leached iron and aluminum from the product

liquor by adjusting the pH to 3.5 to 4.5 with lime or lime-stone, it is possible to reduce the amount of lime or lime-stone required by adjusting the pH only up to 2.5 to 3.0 and then reheating the product liquor to 300 to 400°F. to precipitate basic aluminum and iron sulfates.

The step of neutralizing the excess acid and adjusting the pH to precipitate the iron and aluminum compounds may be combined into a single step when the neutralizing agent used is capable of imparting the desired alkalinity. When neutralizing the excess acidity with ore or with minerals too poor in nickel or cobalt values to warrant their being leached directly with sulfuric acid, it is necessary to carry out the excess acid neutralization and pH adjustment as separate steps.

After the adjustment of the pH of the product liquor to precipitate the iron and aluminum compounds, the separation and recovery of the cobalt and nickel values from the so purified product liquor, either together or separately, may be effectuated in accordance with the general procedures outlined below.

1. In accordance with one procedure, the nickel and cobalt can be completely precipitated and separated from the purified product liquor and can then be redissolved either in ammoniacal solutions to form soluble ammine complexes or in acid to give purified concentrated solutions from which the nickel and cobalt values can then be recovered.

The nickel and cobalt can be completely precipitated by:

- A. Boiling the solution with a slight excess of calcium carbonate.
- B. Adjusting the pH up to 6.5 or as high as possible with calcium carbonate and then completing precipitation with lime or other alkaline reagents.

- C. Adjusting the pH up to 7.0 to 8.0 with lime or other alkaline agents capable of imparting the necessary alkalinity.

5 The nickel and cobalt values redissolved in the ammoniacal or acid solutions can be recovered directly as metals by reduction with hydrogen. On the other hand, the nickel and cobalt can be separated by other means for ultimate recovery, such methods of separation being:

- 10 a. Controlled distillation of complex amine carbonate solutions.
b. Ion exchange.
c. Selective precipitation of nickel carbonate with CO₂.
d. Solvent extraction.

15 2. In accordance with the second procedure, the purified product liquor can be treated directly for combined removal or selective removal of nickel and cobalt by ion exchange, ion migration, or solvent extraction techniques.

20 Precipitation of the nickel and cobalt from purified product liquor as referred to in the first procedure, can be carried out in a manner which will have a marked influence on the solubility of the precipitate in the reagents employed for further processing and separation of the nickel and cobalt.

25 The composition of the nickel/cobalt precipitate can be controlled within a range varying from substantially normal carbonates to hydroxides, depending on the pH adjustment reagents employed in the precipitation step. A wide choice of reagents is available but compounds such as CaCO₃ (limestone, etc.), calcium hydroxide, sodium carbonate, and sodium hydroxide are typical of commercially feasible reagents.

30 Likewise, many ammonium compounds can be employed to redissolve the nickel/cobalt precipitate produced in the step described immediately above. The compound or compounds

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selected will depend upon the process used to convert the nickel and cobalt into products suitable for further processing. Representative ammonium compounds which may be employed alone or in combination are ammonium hydroxide, ammonium carbonate, ammonium sulfate and ammonium acid sulfate.

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Other features and advantages of the invention will appear from the diagrammatic flow sheets illustrating special embodiments of the invention shown in the accompanying drawing in which:

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Fig. 1 is a flow chart indicating the paths of flow and the treatment of materials in a typical procedure for extracting the nickel and cobalt values from the oxidic mineral bearing them.

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Fig. 2 is a modification of the process of Fig. 1 in which the tailings and the precipitated aluminum and iron compounds are combined before being washed and in which the residual lean liquors and the wash water, if any, are recycled to the ore pulping system.

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Fig. 3 is a modification of the process of Fig. 1 in which the product liquor is neutralized in a preleaching step and in which the wash liquor is recycled to the system in advance of the leaching step.

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Fig. 4 is a modification of the process of Fig. 2 in which the first pH adjustment is made by the utilization of an off-grade ore and an alkaline neutralization agent but in which the lean residual liquor is not recycled.

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Referring particularly to Fig. 1 of the drawings for illustrative details of preferred embodiments, ore in its natural state, or ground, if desired, is mixed with water to give an ore suspension or slurry containing 45% solids.

The ore suspension is then flowed into a leaching autoclave or, alternatively, through a heater and heated to leaching temperature under pressure and thereafter introduced into the leaching autoclave. The leaching temperature is 475°F.

5 The heating may be advantageously accomplished through a plurality of stages by heating first with low pressure steam and later with high pressure steam. The sulfuric acid necessary to leach the nickel and cobalt values from the ore is added to the ore suspension in the autoclave either before or

10 after the ore suspension has been raised to the desired leaching temperature.

After the leaching has been completed, which normally requires not more than three hours, the suspension is flowed from the autoclave and flashed in a vessel at lower pressure, and the product liquor is separated from the residual solids or ore tailings which are passed to the tailings washing system. The excess acid of the separated product liquor is then neutralized and the pH of the separated product liquor is adjusted to 3.5 to 4.5 by injection of an alkaline agent, such as lime or limestone, to precipitate out aluminum and iron. The precipitate containing the iron and aluminum is washed and the wash liquor reintroduced into the purified product liquor.

Following the separation of the iron and aluminum and other element compounds precipitating at pH's of 3.5 to 4.5, the pH of the purified product liquor is adjusted to a level of 7.0 to 8.0 by the introduction of additional alkaline agents, such as lime. In this manner the nickel and cobalt are precipitated and the precipitate is separated from the liquor. The precipitated nickel and cobalt compounds, being

in a concentrated, purified state, are then ready for refining, in which the cobalt and nickel are separated and recovered by any of a variety of techniques, such as those outlined previously under the first described procedure for the treatment of purified product liquor.

5 The lean residual liquor remaining after the nickel and cobalt are precipitated may be discarded to waste. The tailings are advantageously washed with water and the resultant wash liquor reintroduced into the main process stream
10 by injection into the system following the leaching step.

15 As shown in Fig. 2, the illustrated process is generally the same as in Fig. 1 with the exception that the precipitate obtained from the first pH adjustment is combined with the tailings instead of being washed separately and the residual lean liquor and the additional wash water, if any, are recycled to the ore pulping stage of the system. By proceeding in this manner, the washing of the precipitate from the first precipitation step is eliminated, but if limestone is used
20 as the neutralizing agent, calcium sulfate will be mixed with the tailings and will complicate any subsequent recovery
25 of iron values.

30 The tailing wash liquor containing the residual lean liquor is recycled to the ore preparation system for preparing additional ore for leaching. Recycling the wash liquor containing residual lean liquor to the system in advance of the leaching step serves to recover entrained nickel and cobalt values.

35 The amount of recycled liquor available may in some cases exceed the amount required for proper ore pulp dilution for leaching. Thus, after separating the nickel and cobalt

values, it may be advantageous in some cases to concentrate the residual liquor by evaporation before it is used to wash the tailings or to concentrate the wash liquors before they are recycled to the ore preparation stage.

5 As shown in Fig. 3, the excess acid is neutralized by recycling the product liquor to preleach the ore. The advantages of such a procedure have been discussed hereinbefore and include the advantage of reducing the over-all consumption of acid to the extent that values are leached from the ore
10 in the neutralizing step.

In the modification shown in Fig. 4, excess acid is neutralized and the first pH adjustment is made with off-grade ore and alkaline neutralizing agent. Also, the precipitate from the first pH adjustment is treated with wash liquor
15 from the tailings washing system. In this way, the aluminum and iron precipitate will be treated with a wash liquor containing acid which will recover co-precipitated nickel and cobalt.

The leaching processes of the present invention are applicable to oxidic minerals other than those hereinbefore disclosed including ores found in Brazil, Venezuela, New Caledonia, the Philippines, and Indonesia.

It should be understood that the present invention is not limited to the specific embodiments and procedures hereinbefore discussed but that it extends to all other procedures and improvements which will occur to those skilled in the art upon consideration of the disclosure and the details and the scope of the claims appended hereto.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A process for the recovery of nickel, cobalt and other non-ferrous metals from lateritic ores containing also iron which comprises, subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount not less than 15% of the dry weight of the ore and which will be sufficient substantially only to react with and solubilize the nickel and other non-ferrous metal content upon heating to a temperature of at least 350°F., heating the suspension at such temperature until said reaction and solubilization has occurred and separating the resulting solution containing the solubilized non-ferrous metal content from the spent ore containing substantially all of the iron.

2. A process for the recovery of nickel, cobalt and other non-ferrous metals from lateritic ores containing also iron which comprises subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount between about 15% and 100% of the dry weight of the ore but insufficient to dissolve appreciable amounts of iron, heating the suspension at a temperature of at least 350°F. until the sulfuric acid has reacted with and solubilized the non-ferrous metal content to be recovered and separating the resulting solution containing the solubilized non-ferrous metal content from the spent ore containing substantially all of the iron.

3. A process for the recovery of nickel from nickeliferous oxidic ores containing iron also which comprises, subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount not less than 15% of the dry weight of the ore and not substantially more than that which will be taken up in reaction with the non-ferrous metal content upon heating to a temperature of at least 400°F., heating the suspension at such temperature until said reaction and solubilization has occurred and separating the resulting solution containing the solubilized nickel from the spent ore containing substantially all of the iron.

4. A process for the recovery of cobalt together with any of the metals nickel, copper, zinc and manganese present from lateritic, oxidic ores containing iron also, which comprises subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount not less than 15% of the dry weight of the ore and not substantially more than that which will be taken up in reaction with the non-ferrous metal content upon heating to a temperature of at least 350°F., heating the suspension at such temperature until said reaction and solubilization has occurred and separating the resulting solution containing the cobalt and other solubilized non-ferrous metal content from the spent ore containing substantially all of the iron.

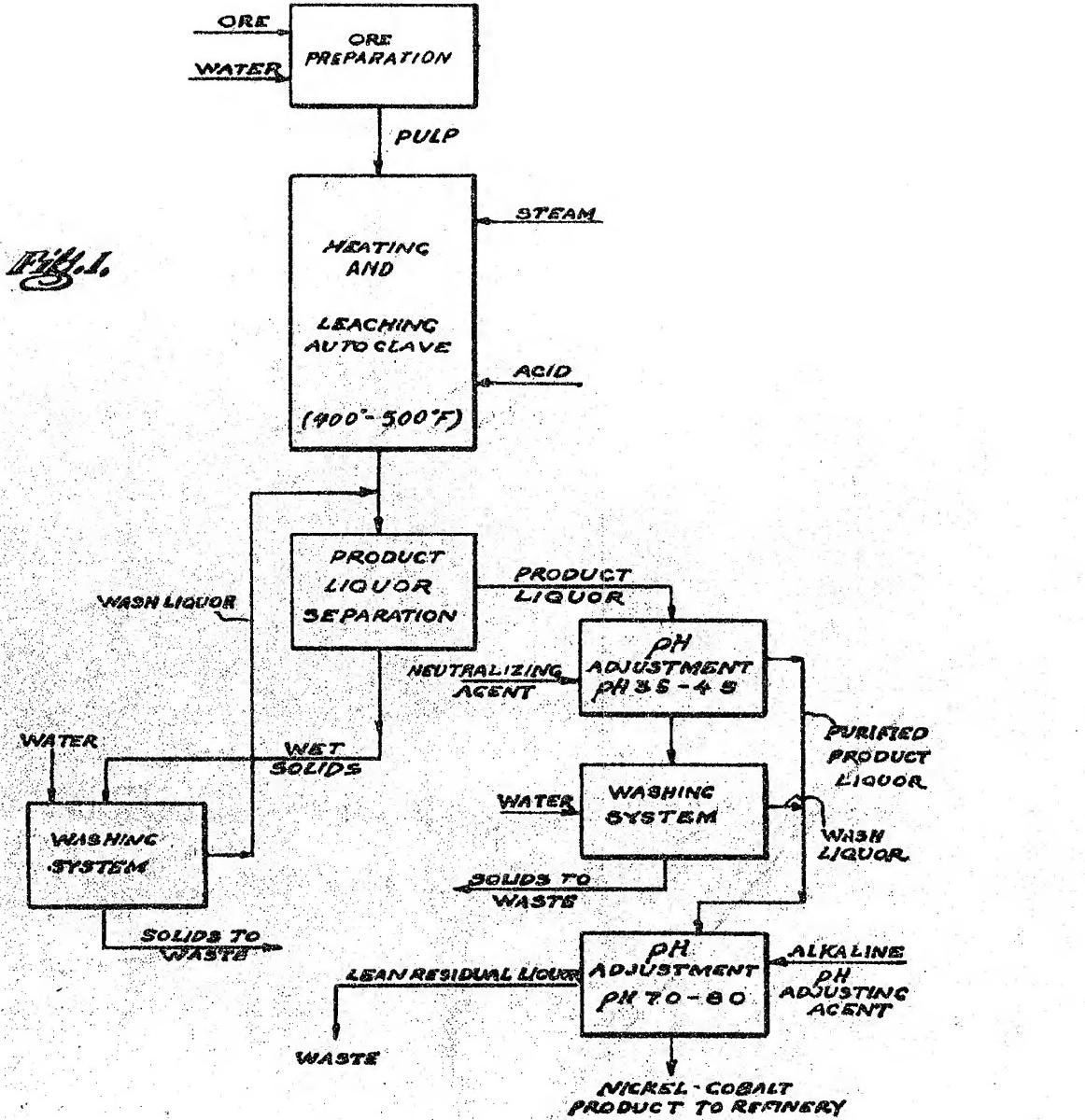
5. A process for the recovery of nickel and cobalt from lateritic, oxidic ores containing also iron which comprises, subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount between about 15% and 100% of the dry weight of the ore, the amount employed being sufficient only to react with and solubilize the non-ferrous metal content which amount is insufficient to dissolve appreciable amounts of the iron content, heating the suspension at a temperature of at least 400° F. until the sulfuric acid has reacted with the nickel and cobalt content to be recovered, and separating the resulting solution containing all of the solubilized nickel and cobalt content from the spent ore containing substantially all of the iron.

6. A process for the recovery of nickel, cobalt and other non-ferrous metals from raw, low grade nickeliferous lateritic ores containing also iron which comprises, subjecting the ore in a flowable water suspension to the action of sulfuric acid in an amount not less than 15% of the dry weight of the ore and not substantially more than that which will be taken up in reaction with the non-ferrous metal content upon being heated to at least 400° F., heating the suspension at such temperature until the nickel content has been substantially all solubilized, and separating the resulting solution containing substantially all of the solubilized nickel and cobalt content from the spent ore containing the iron.

7. A process for the recovery of nickel, cobalt and other non-ferrous metals from lateritic ores containing also iron which comprises, forming a flowable aqueous suspension of the ore, flowing the suspension into a reaction zone, introducing sulfuric acid into said zone in an amount between about 15% and 100% of the dry weight of the ore but not substantially more than will react with the non-ferrous metal content in the hot leaching step to follow, the amount of water introduced into said zone being adequate to dissolve subsequently the non-ferrous metal content to be recovered solubilized during heating, heating the ore-acid-water mixture in said zone to a temperature of at least 350°F. until the non-ferrous metal content to be recovered has been solubilized and dissolved in the water, and on cooling, separating the resulting solution from the spent ore containing the iron.

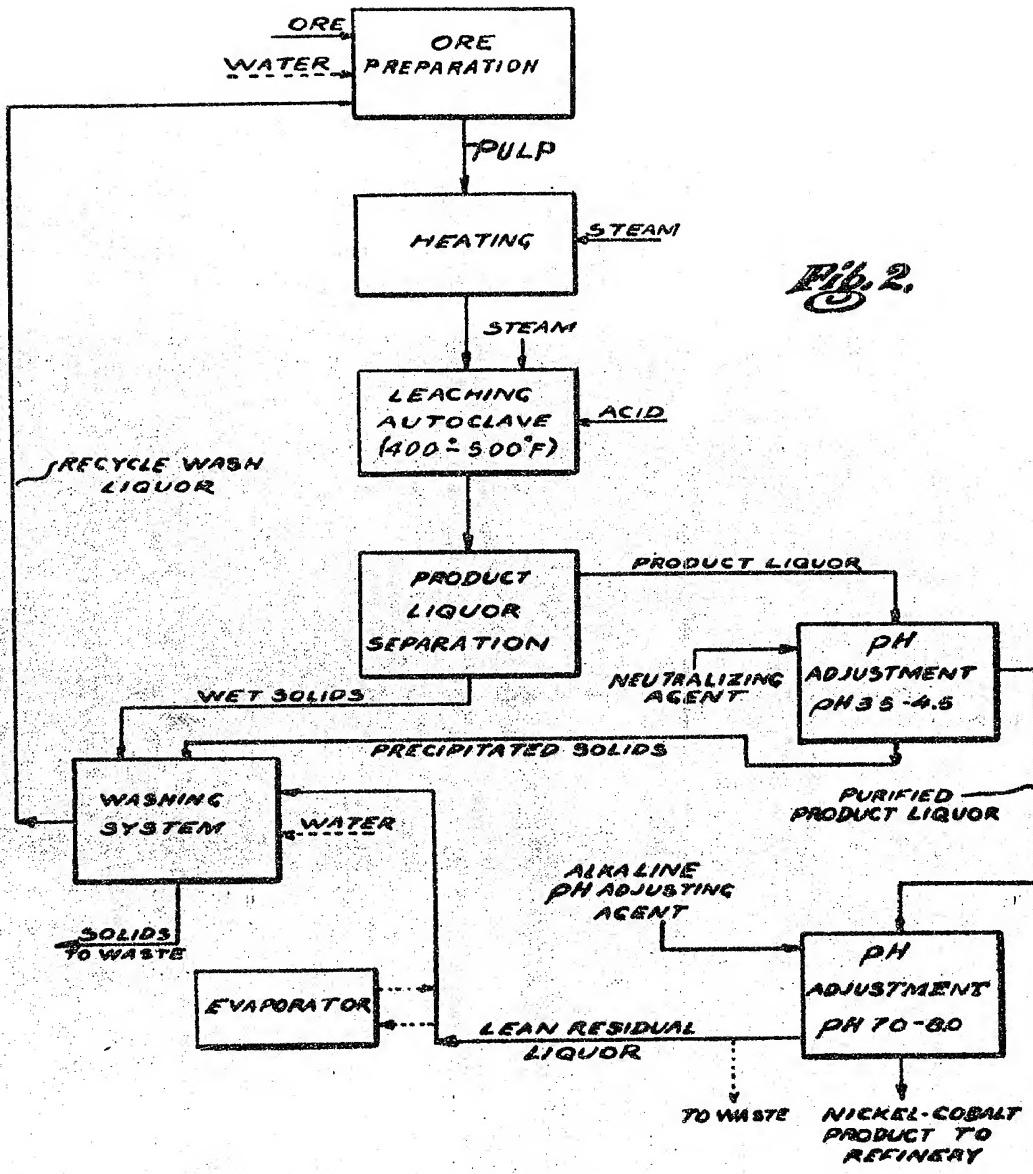
8. A process for the recovery of nickel, cobalt and other non-ferrous metals from lateritic ore concentrates containing iron which comprises, subjecting the ore in water suspension to the leaching action of sulfuric acid in an amount not less than 35% of the dry weight of the concentrate and which will be sufficient, but not substantially more than sufficient, to react with the non-ferrous metal content upon heating to a temperature of at least 350°F., heating the suspension at such temperature until said reaction and solubilization have occurred and separating the resulting solution containing the solubilized non-ferrous metal content from the spent concentrate containing substantially all of the iron.

9. A process for the recovery of nickel, cobalt and other non-ferrous metals from lateritic ore concentrates containing also iron, the amount of nickel present being at least 2% which comprises, subjecting the concentrate in water suspension to the leaching action of sulfuric acid in an amount between about 25% and 100% of the dry weight of the concentrate sufficient, but not substantially more than sufficient, to react with the non-ferrous metal content upon heating to a temperature of at least 350°F., heating the suspension at such temperature until said reaction and solubilization have occurred and separating the resulting solution containing the solubilized non-ferrous metal content from the spent concentrate containing substantially all of the iron.



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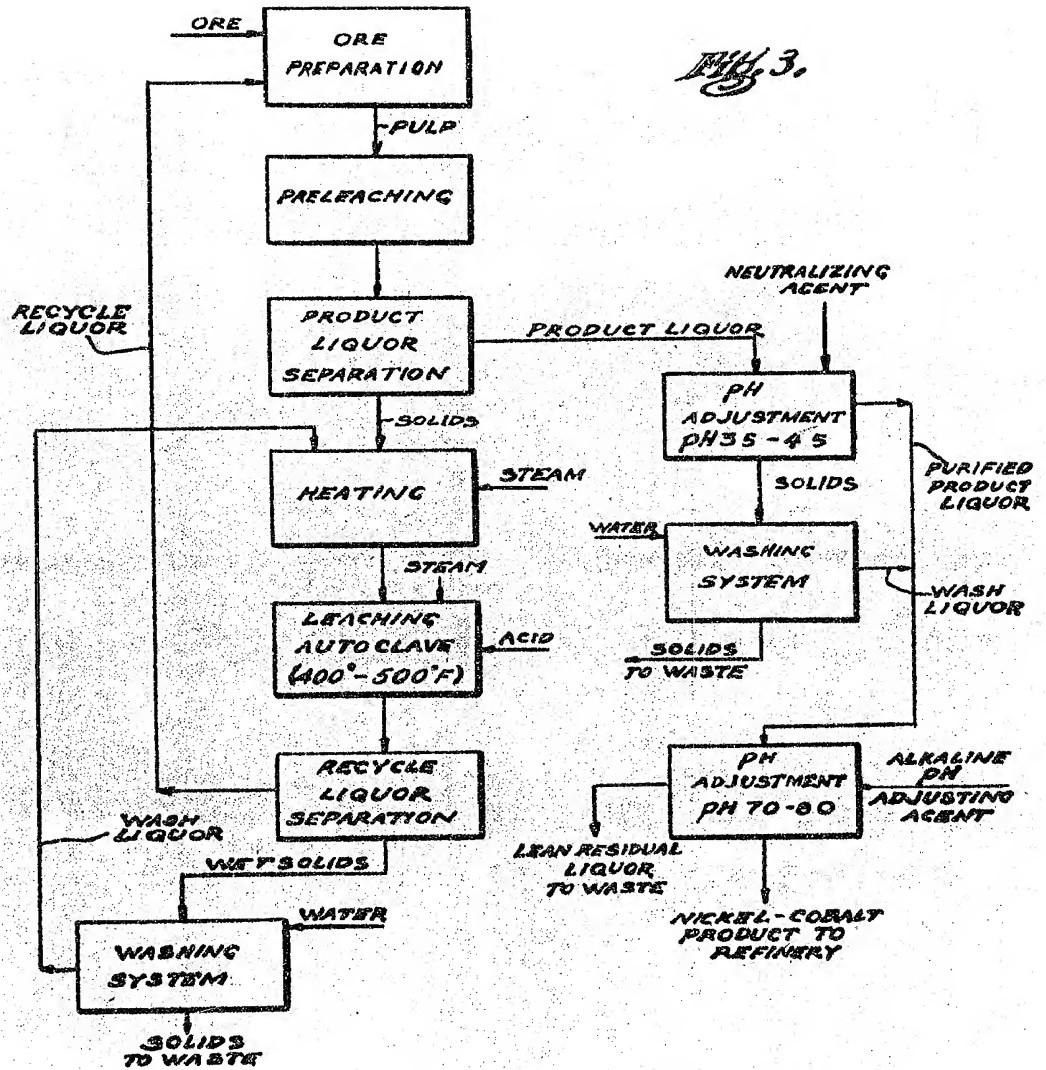
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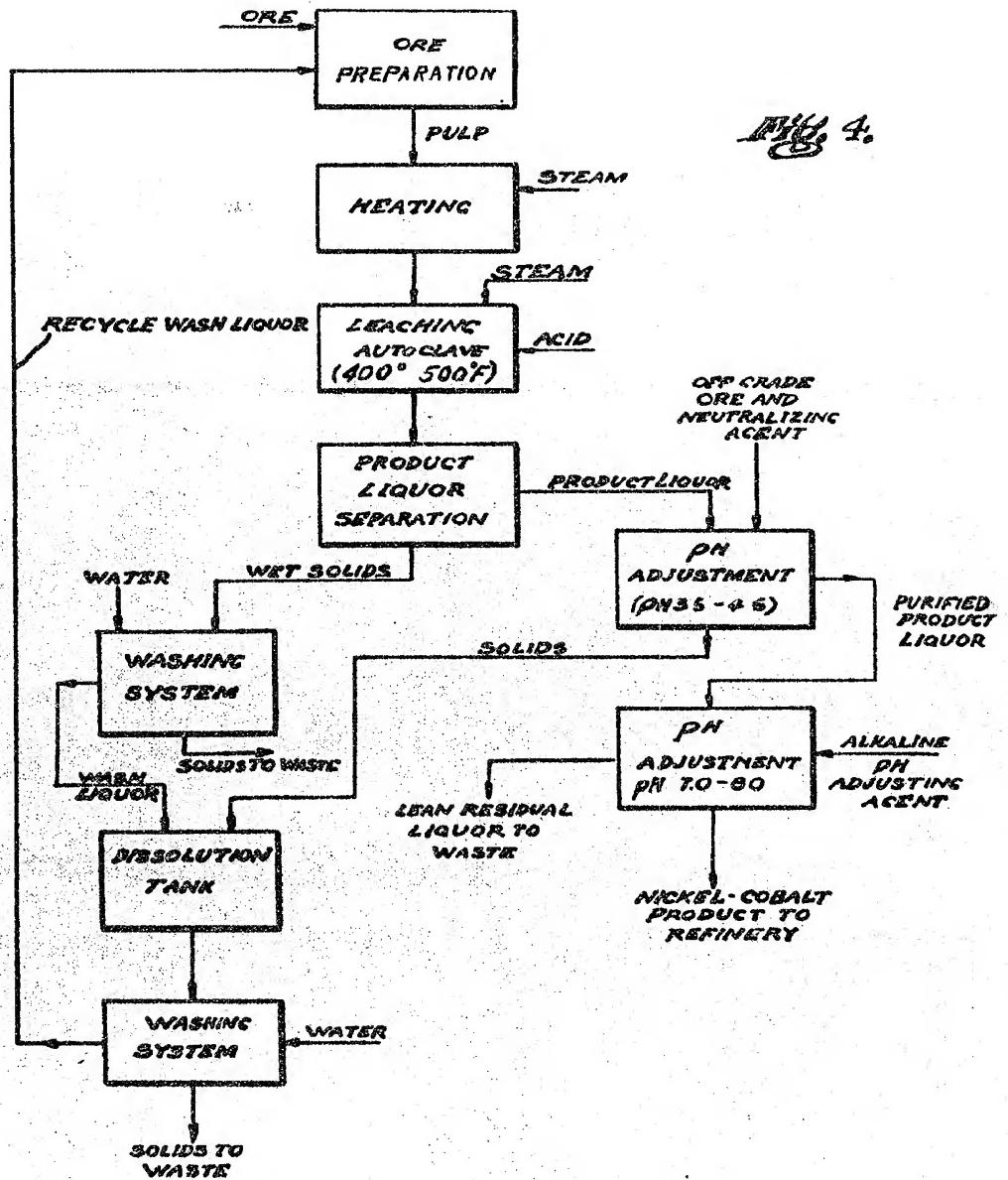


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